

A Software Framework for Mobile Ad hoc Data Communications Using Voice-Centric Tactical Radios



Geoffrey Xie

Department of Computer Science, Naval Postgraduate School

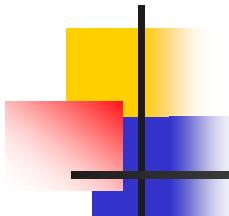
xie@nps.edu

Collaborators:

Steven Brand (Capt, USMC)

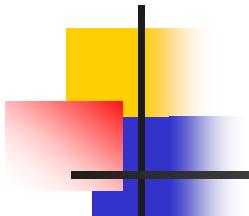
John Gibson

| | | | | | | | |
|---|------------------------------------|--|--|---|----------------------------------|--|---------------------------------|
| Report Documentation Page | | | <i>Form Approved OMB No. 0704-0188</i> | | | | |
| <p>Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p> | | | | | | | |
| 1. REPORT DATE JUN 2006 | | 2. REPORT TYPE | | 3. DATES COVERED 00-00-2006 to 00-00-2006 | | | |
| 4. TITLE AND SUBTITLE A Software Framework for Mobile Ad hoc Data Communications Using Voice-Centric Tactical Radios | | | | | | | |
| 6. AUTHOR(S) | | 5a. CONTRACT NUMBER | | | | | |
| | | 5b. GRANT NUMBER | | | | | |
| | | 5c. PROGRAM ELEMENT NUMBER | | | | | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School, Department of Computer Science, 1 University Circle, Monterey, CA, 93943 | | 5d. PROJECT NUMBER | | | | | |
| | | 5e. TASK NUMBER | | | | | |
| | | 5f. WORK UNIT NUMBER | | | | | |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | | 8. PERFORMING ORGANIZATION REPORT NUMBER | | | | | |
| | | 10. SPONSOR/MONITOR'S ACRONYM(S) | | | | | |
| | | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) | | | | | |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited | | | | | | | |
| 13. SUPPLEMENTARY NOTES The original document contains color images. | | | | | | | |
| 14. ABSTRACT | | | | | | | |
| 15. SUBJECT TERMS | | | | | | | |
| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | | 18. NUMBER OF PAGES 29 | | 19a. NAME OF RESPONSIBLE PERSON |
| a. REPORT unclassified | b. ABSTRACT unclassified | c. THIS PAGE unclassified | | | | | |



Motivation

- State of Practice: Modern C2 capabilities often don't reach front line troops
 - situation awareness still voice centric
 - transition to information centric operation limited by legacy stove-pipe system designs
- State of Art: Mobile ad hoc networking is becoming a commodity technology in the civilian sector
 - ubiquitous high speed access to multimedia
 - minimum configuration

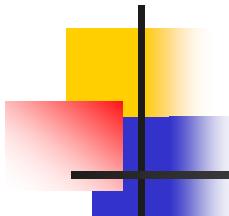


Research Objectives

- Investigate feasibility of providing data networking capability to small units with legacy radios
- Minimize requirement for additional “networking hardware”

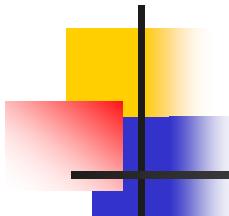
Proof of Concept via SINCGARS Radio





System Components

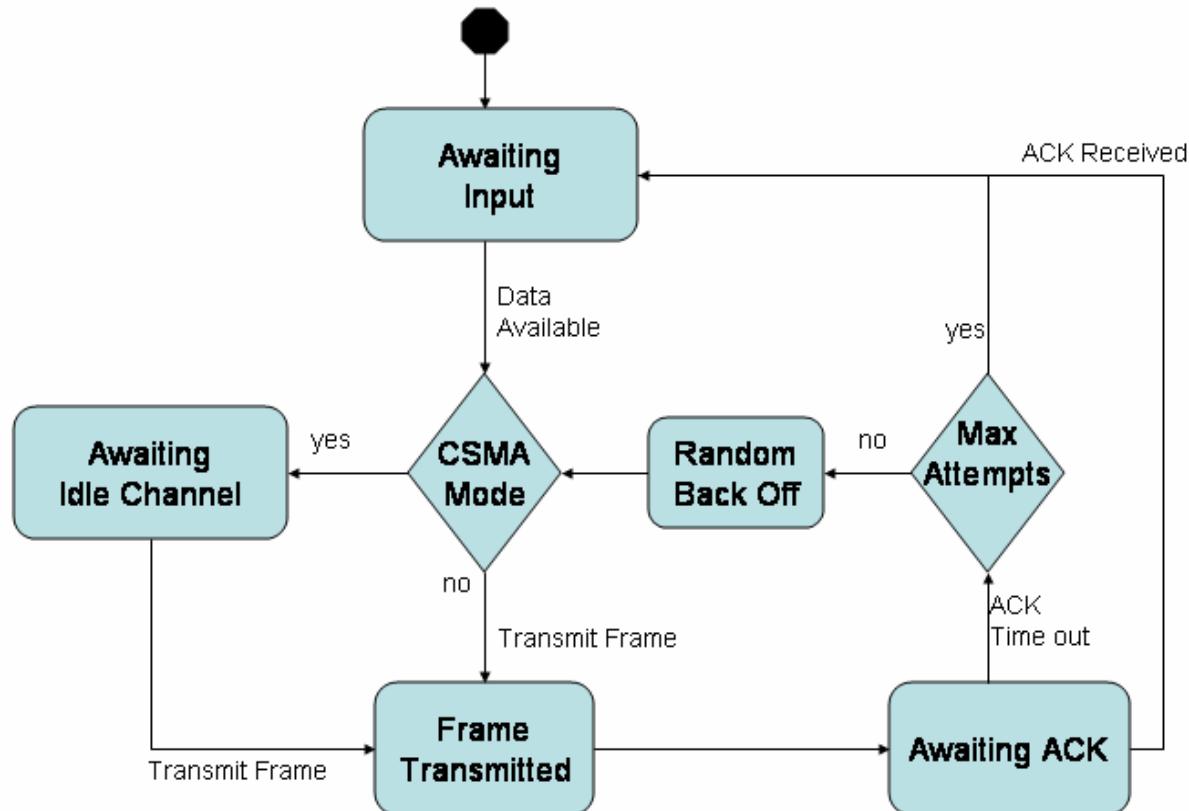
- Data Link Protocol
- Multi-hop Routing Capability
 - Expected Relative Positioning Routing with Congestion Avoidance (ERP/CA)
- Tactical Chat Application
 - SINCGARS Data Demo

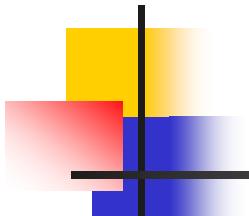


Data Link Protocol

- Media Access Control
 - ALOHA & CSMA Functionalities
- Flow Control and Error Control
 - Simple Stop-and-Wait
- “802.11-Lite”
 - Minimum subset of 802.11 features
 - MAC, Encapsulation, Error Control
 - No sync, beacons, probes, NAVs, authentication, etc.

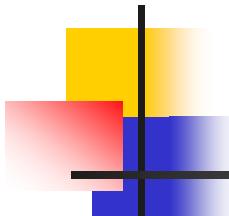
Media Access Control





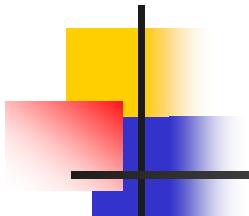
ERP/CA Routing Protocol

- Operation-aware
 - Exploit Operational Knowledge about Node Movements
- Bandwidth-Efficient
 - Minimize Overhead of Control Traffic



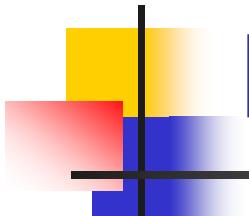
Operational Knowledge

- TTPs (Tactics, Techniques, and Procedures) Used by Tactical Units
 - Military formations
 - Wingman concept
- Unit Leaders Maintain Physical Proximity
 - Maintain Radio Contact
 - Facilitates Command and Control



Operation-aware Routing

- Route Selection Based Upon Relative Positions of Nodes Within Formation
 - Relative positions between nodes (or node relationships) are policy-driven
 - Links between nodes with “close” relationship tend to be persistent
- Mechanism: Nodes wait for a period of time before responding to route request
 - Node with closest relationship to destination responds to route request first

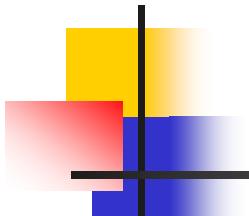


Route Response Wait Formula

$$\text{RRW} = \text{CW} + \text{CAV} + \text{IRW} \text{ milliseconds}$$

CW values:

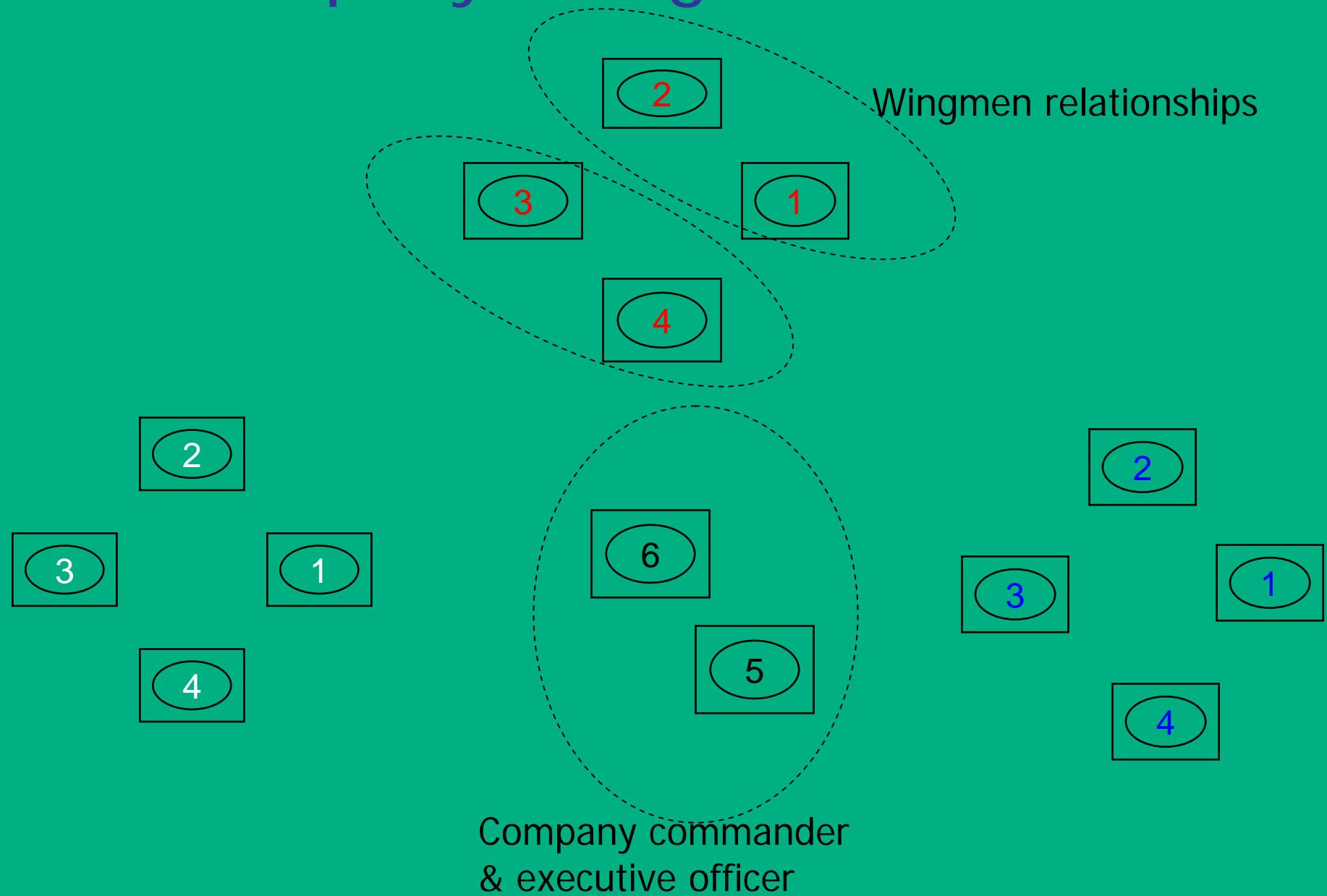
| Relationship Category | Wait Time Assigned (ms) |
|-----------------------|-------------------------|
| GOOD | 1500 |
| BETTER | 1000 |
| BEST | 500 |
| DIRECT LINK | 0 |



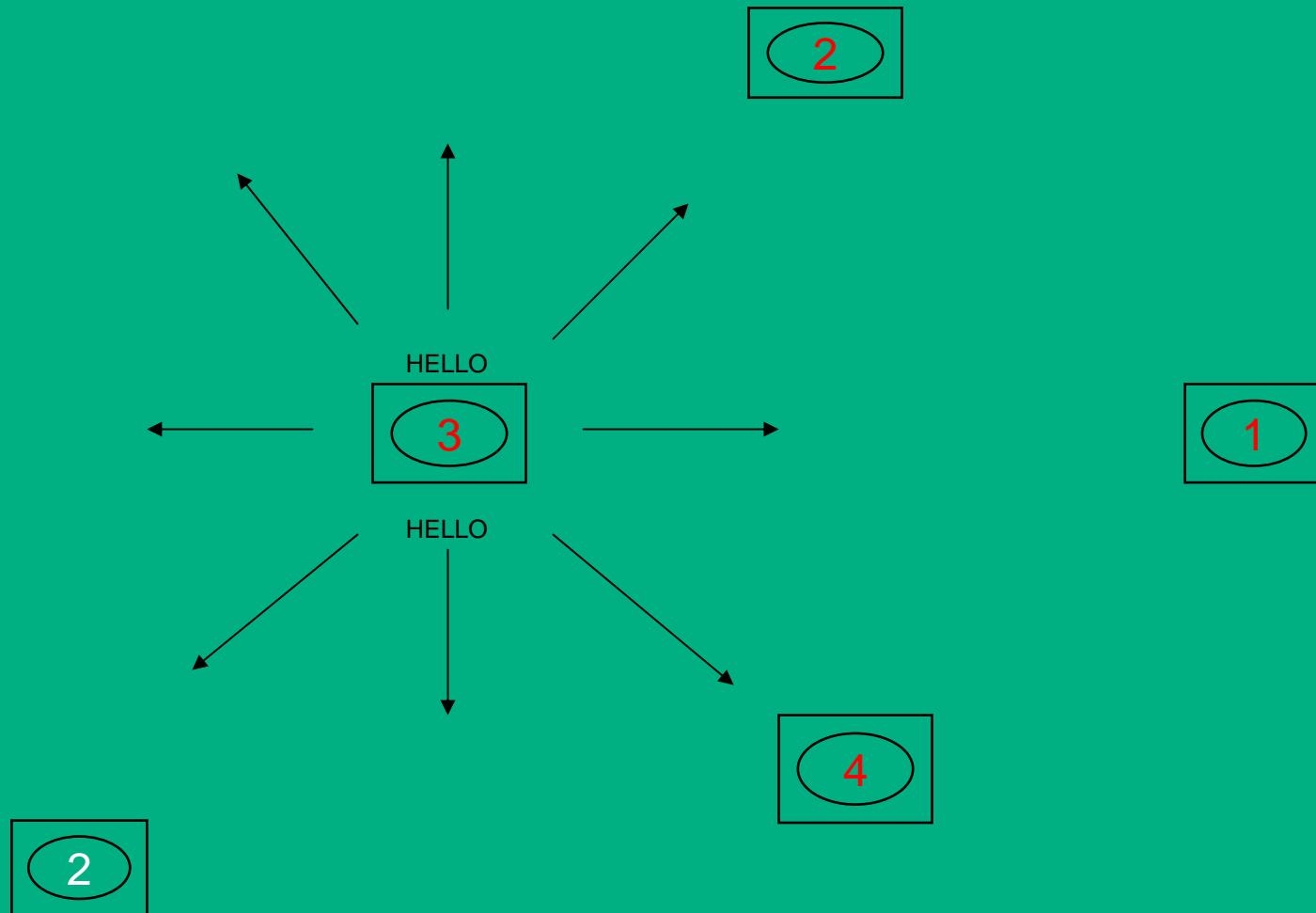
Bandwidth-Efficient Routing

- On-demand Route Discovery
- Controlled Flooding
 - Node stops flooding if it has route to destination
- Node Relationships are Input to Protocol
 - No need to discover them (**this is novel!**)

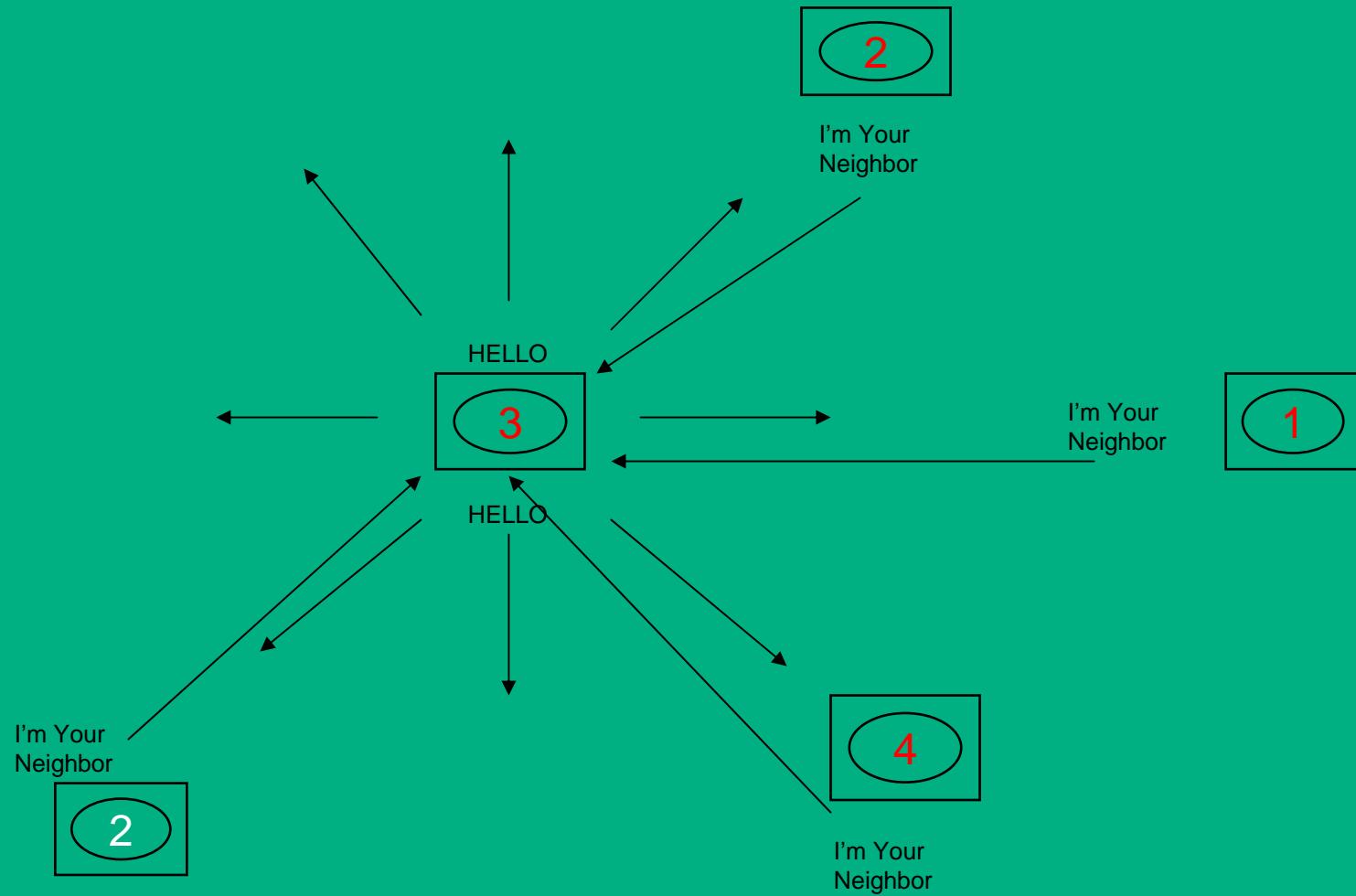
Tank Company Wedge Formation

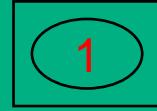
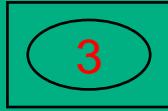
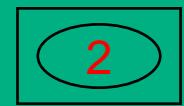


Neighbor Discovery

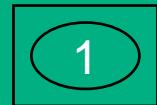


Neighbor Discovery (HELLO Response)





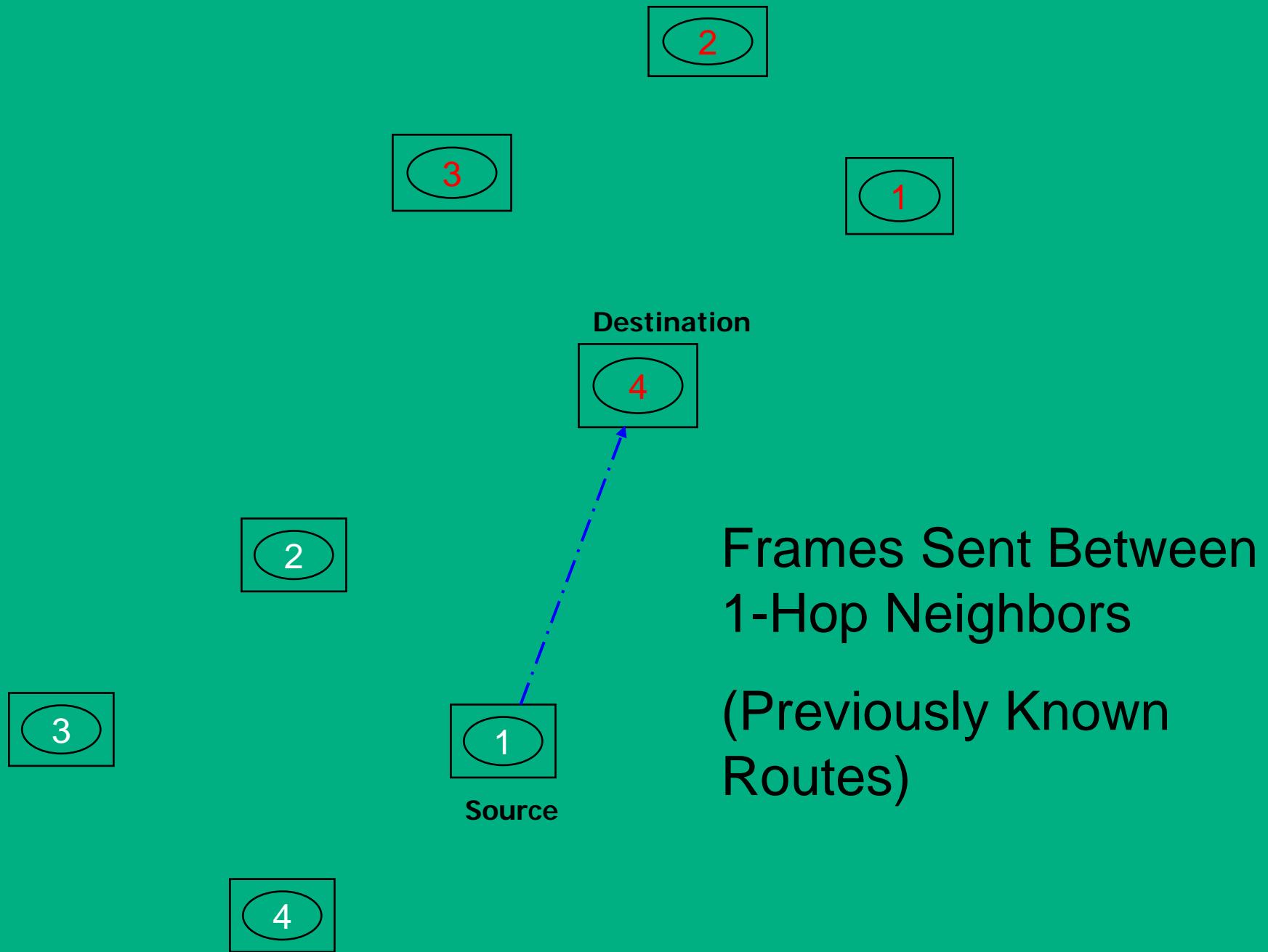
Source

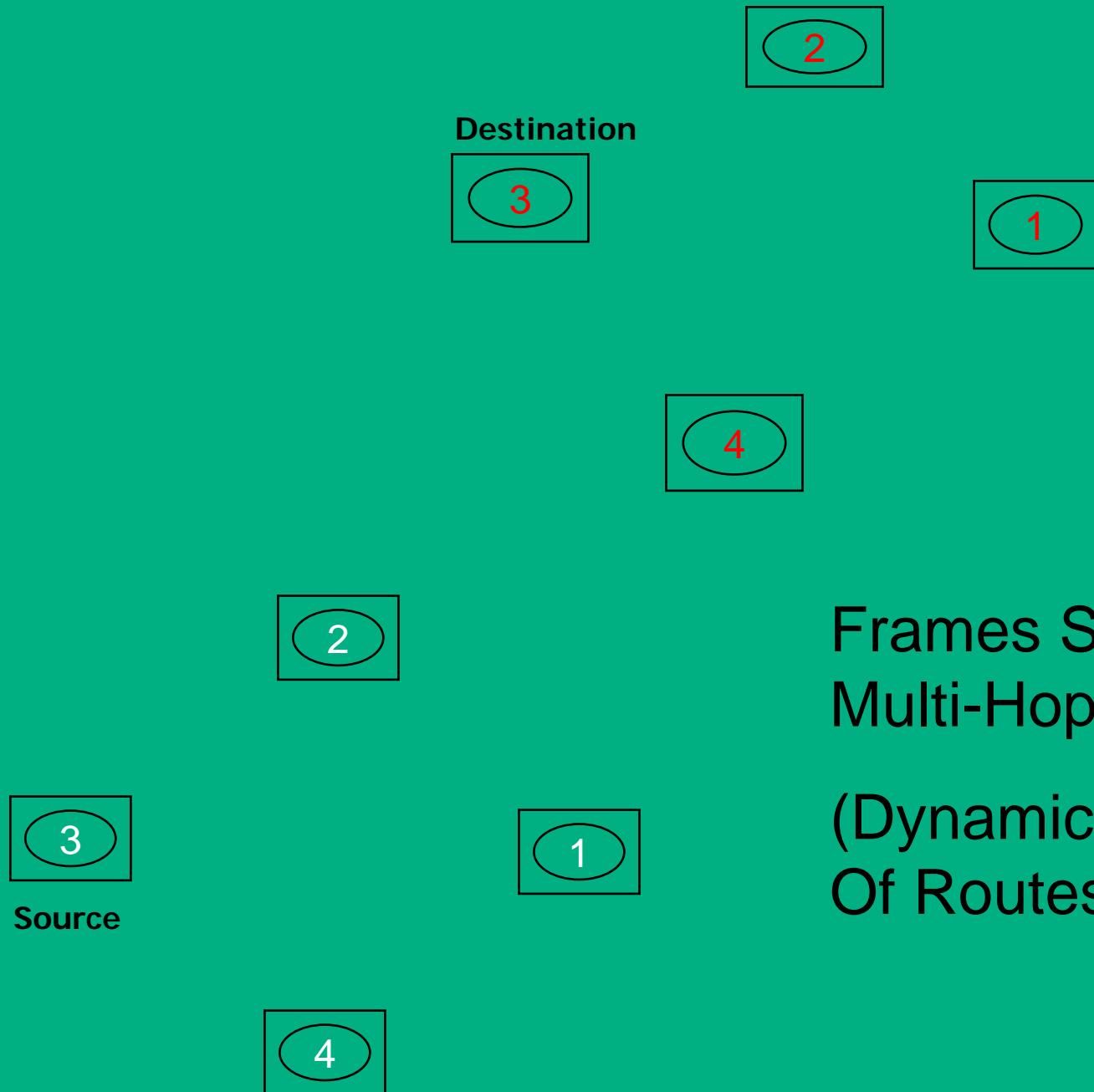


Destination

Frames Sent Between
1-Hop Neighbors

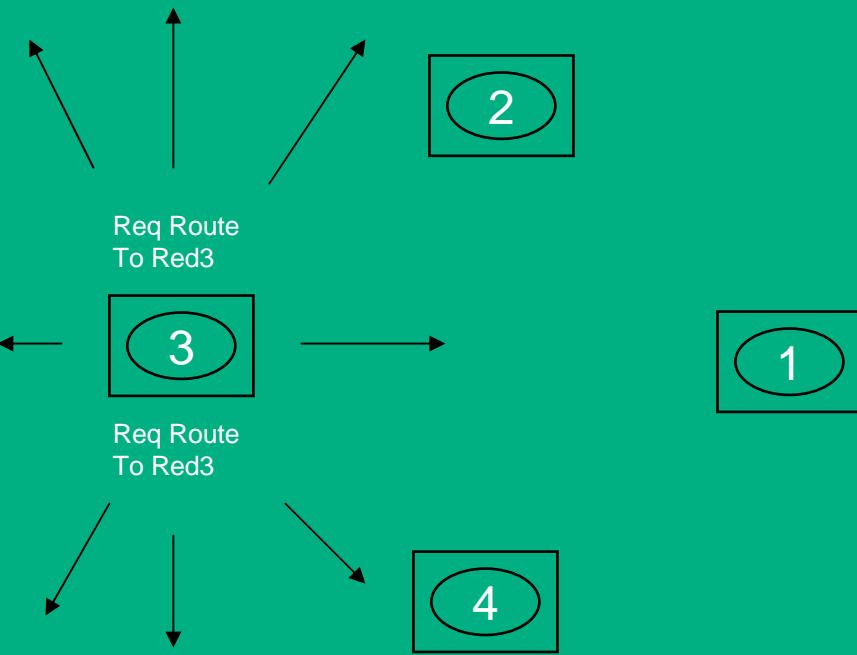
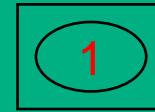
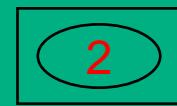
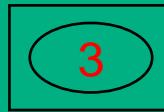
(Previously Known
Routes)



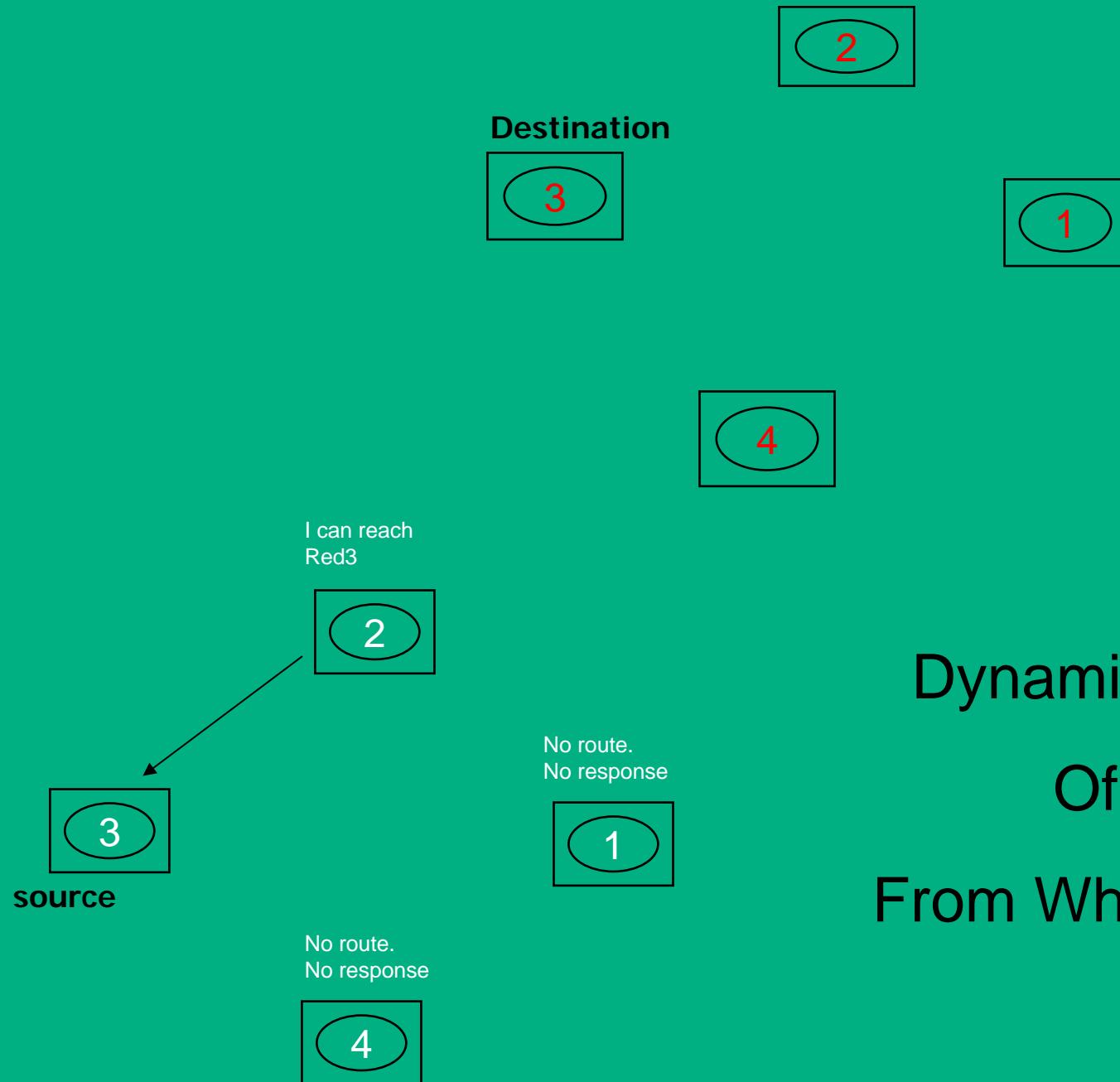


Frames Sent Between
Multi-Hop Neighbors
(Dynamic Discovery
Of Routes)

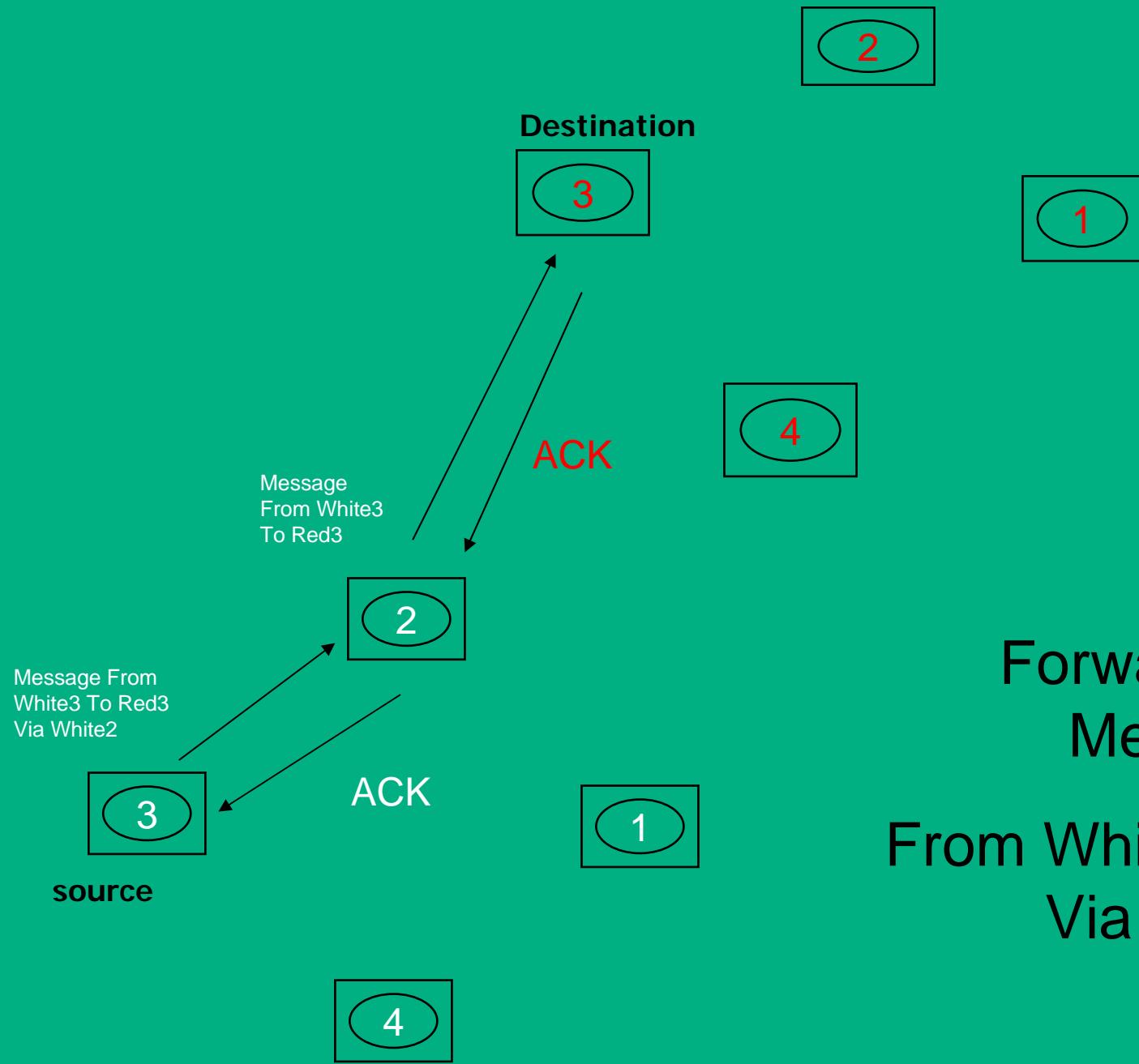
Destination



Dynamic Discovery
Of Route
From White3 To Red3

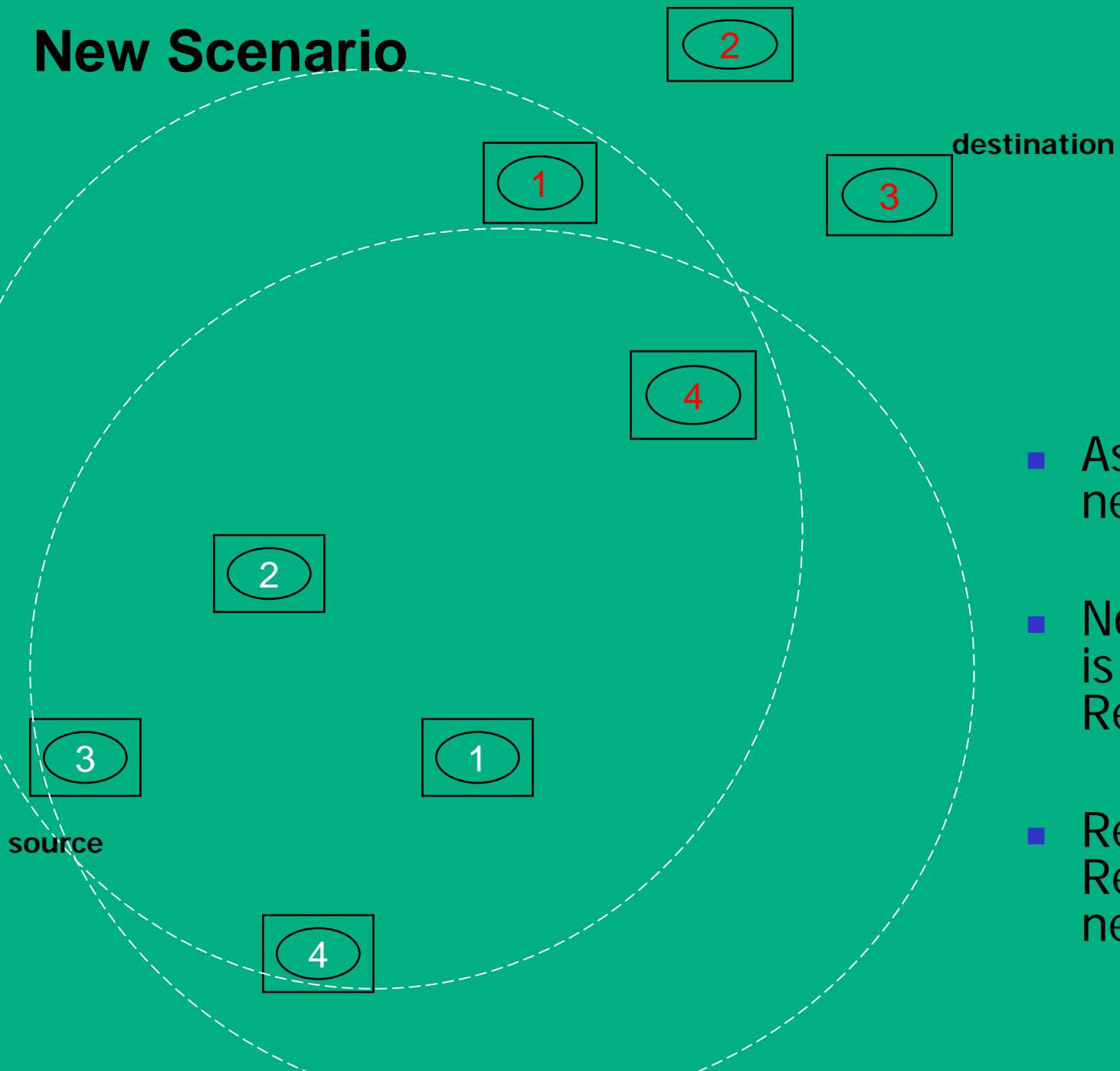


Dynamic Discovery Of Route From White3 To Red3



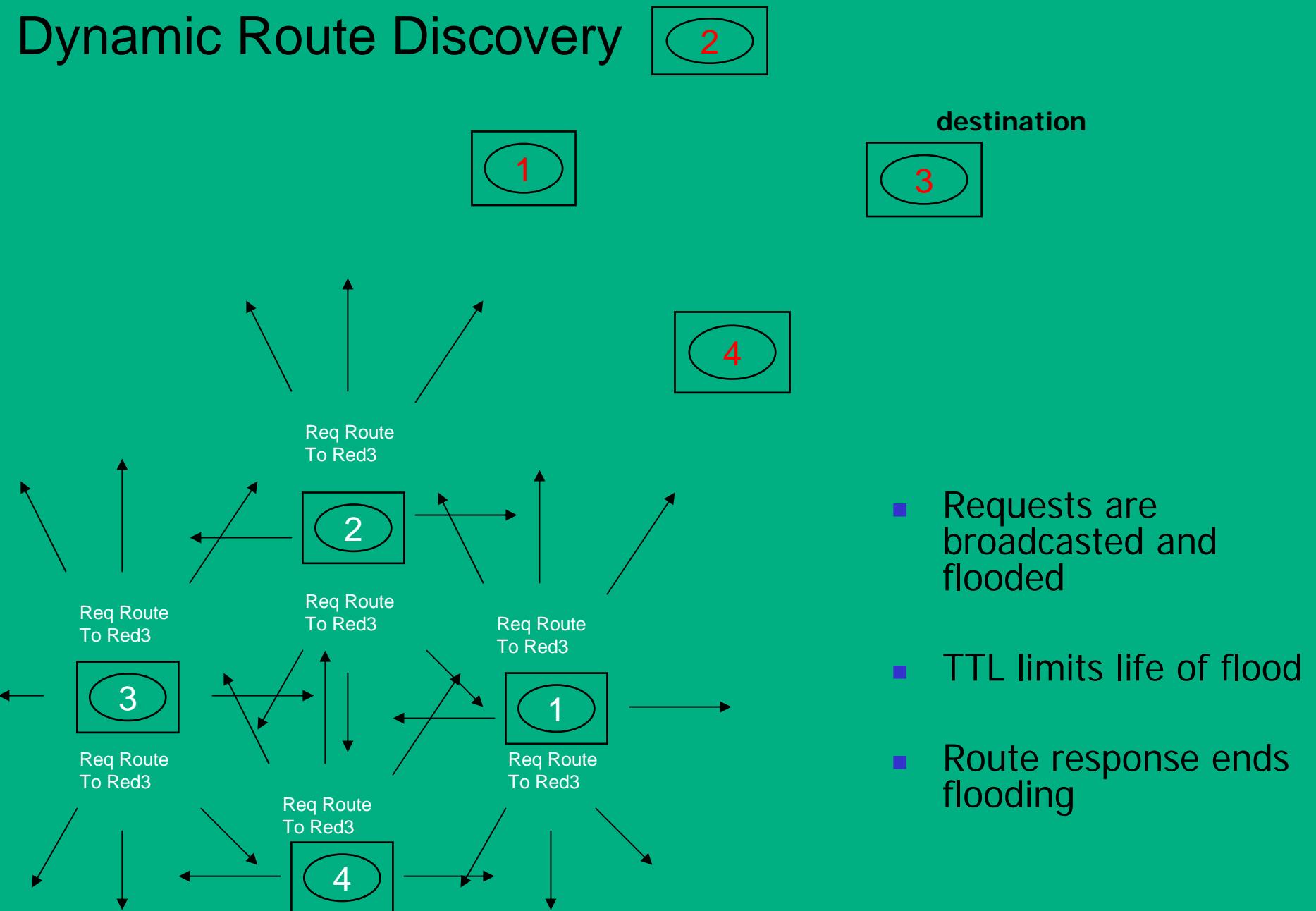
Forwarding Of
Message
From White3 To Red3,
Via White2

New Scenario



- Assume this new state:
- No white node is in range of Red3
- Red3 and Red1 are in new positions

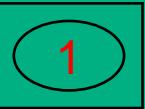
Dynamic Route Discovery



Response To Route Request

Not sent because
Red4's response is
heard first.

I can reach
Red3



2

destination

3

I can reach
Red3



4

2

I can reach
Red3



1



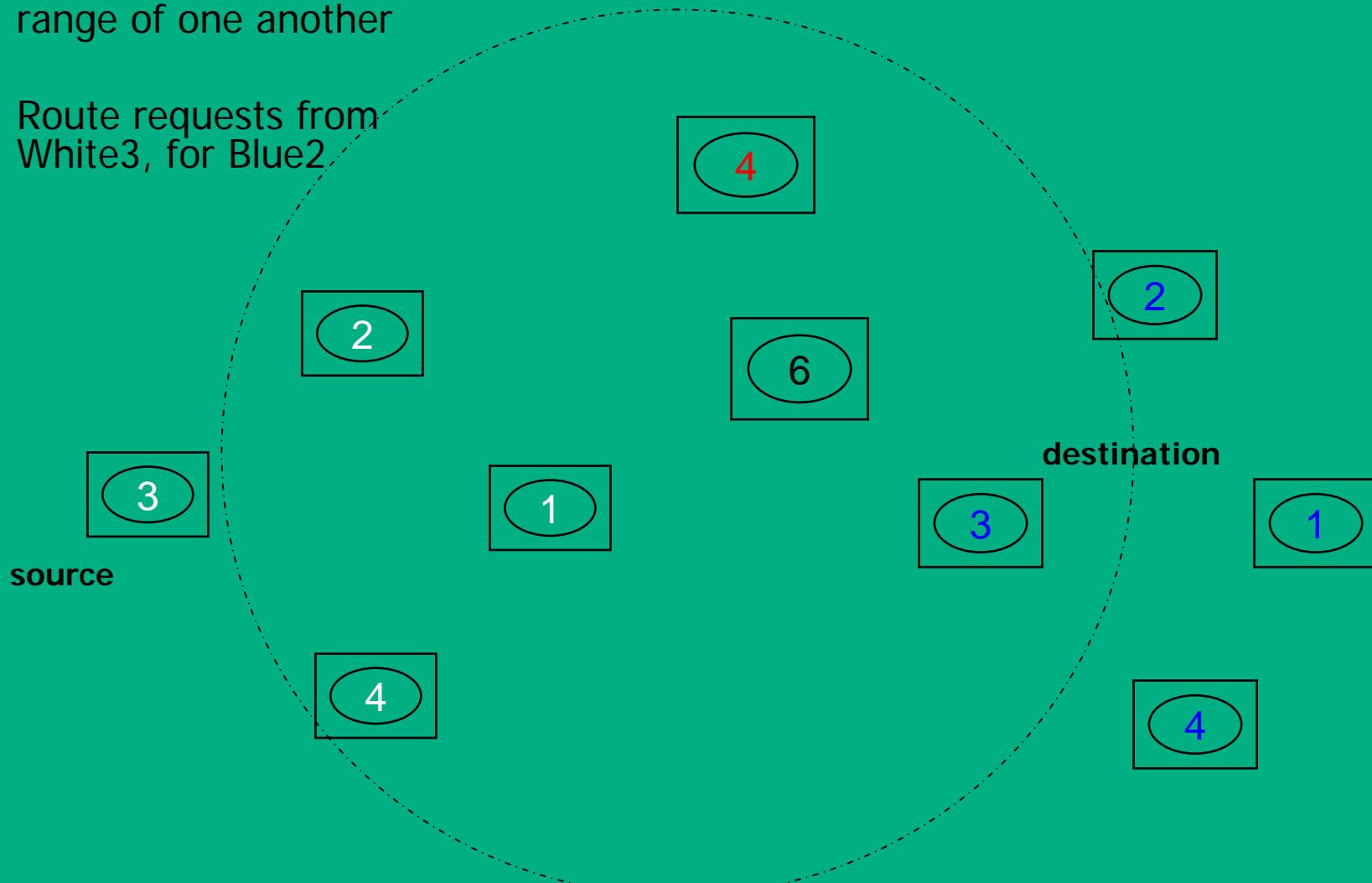
source

4

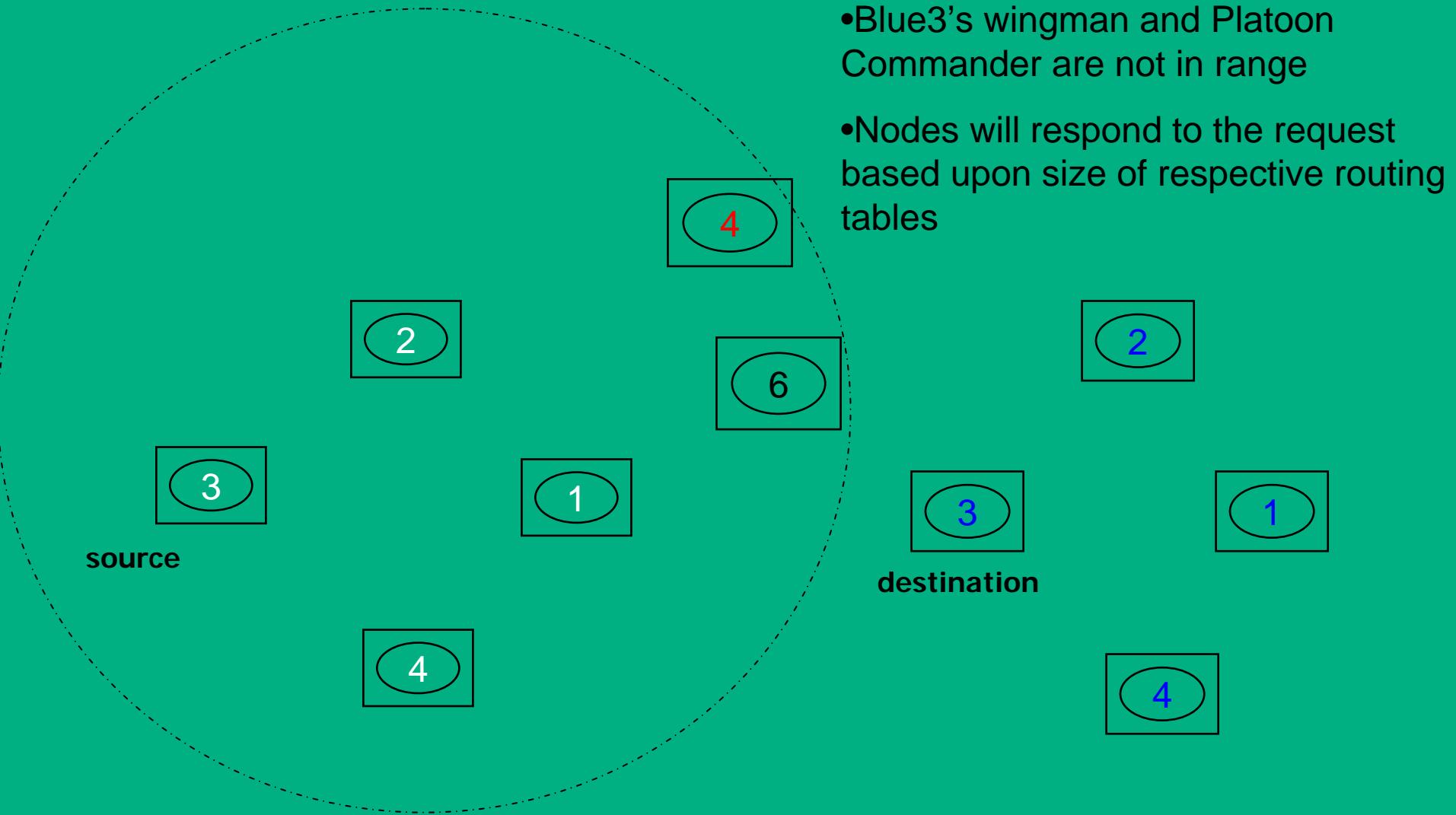
- All responses are unicast
- Responses are based on categories
- Actual destination responds first
- Wingman responds next
- Followed by Platoon Commander
- Last to respond are all others with a route

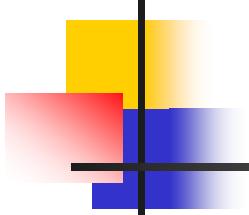
Congestion Avoidance

- Assume all within circle are within range of one another
- Route requests from White3, for Blue2



Congestion Avoidance

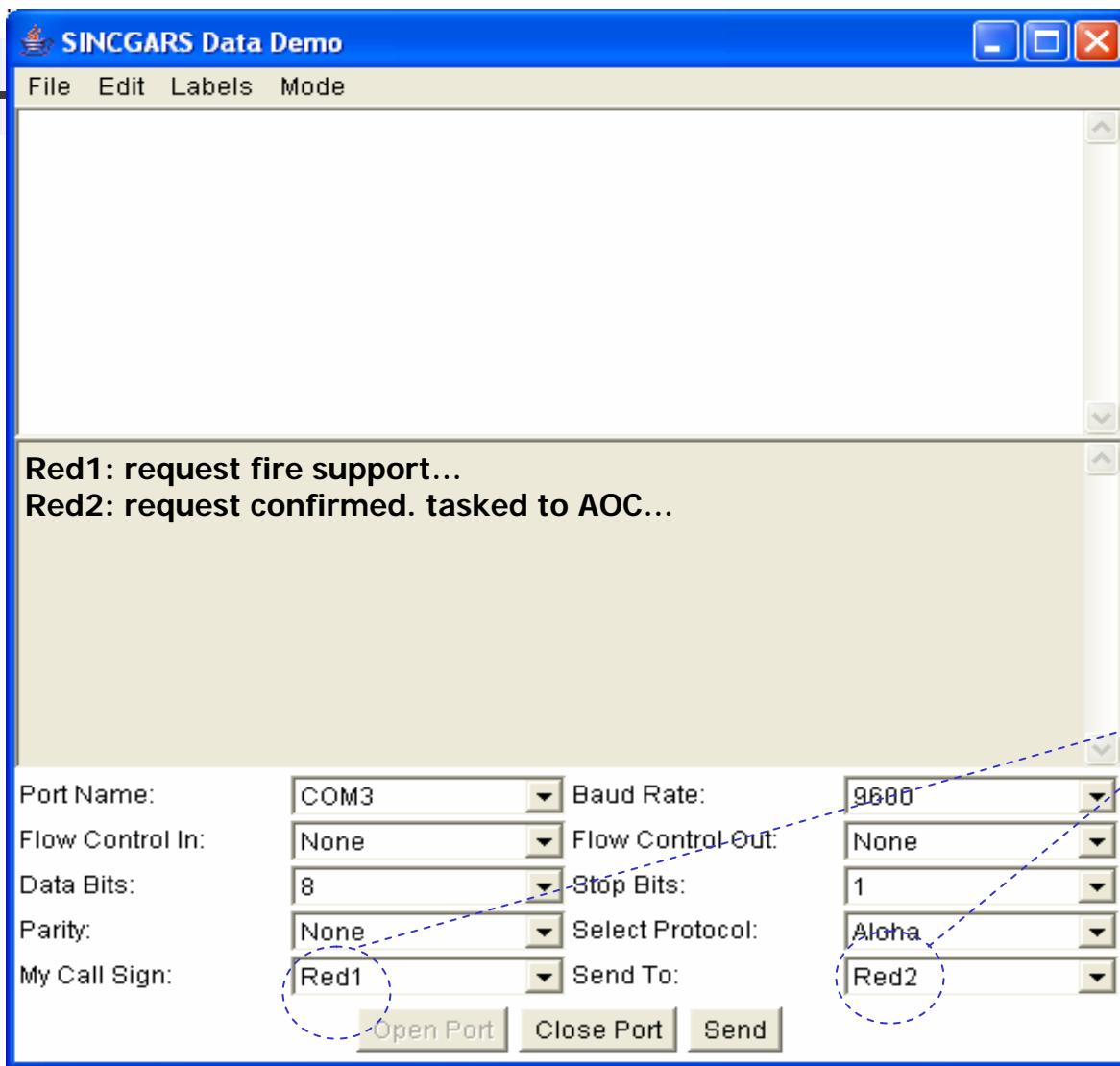




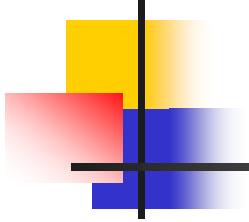
SINCGARS Data Demo

- Tactical Chat Application
- File Transfer Capability
- Runs Directly Above Link Layer

SINCGARS Data Demo



Call signs reflect node relationships, e.g., Red1 and Red2 are wingmen to each other.



Conclusions

- Demonstrated feasibility to deploy data centric C2 capabilities with legacy voice centric radios using *only* software
- Many opportunities exist to develop low cost *stop-gap* C2/network centric capabilities for front line troops